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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
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☐ *Additional inventors are being named on the ^ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

METHOD AND SYSTEM OF CONTROLLING AN LCD PANEL

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☐ Application Data Sheet. See 37 CFR 1.76 ☒ Other (specify) postcard

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☐ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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Respectfully submitted,

Date: 04 / Mar / 2004

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REGISTRATION NO. *(if appropriate)*: 52,388

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USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

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P-6519-USP

METHOD AND SYSTEM OF CONTROLLING AN LCD PANEL

Inventors: Ilan Ben-David

Field Of The Invention

The invention relates to color display systems generally and, more particularly, to liquid crystal display panels.

Background

Fig. 1 schematically illustrates a conventional color Liquid Crystal Display (LCD) system 100. System 100 may include an array 108 of liquid crystal (LC) elements (cells) 104, for example, an LC array using Thin Film Transistor (TFT) active-matrix technology, as is known in the art, and a tri-color filter array, e.g., a RGB filter array 106, juxtaposed with LC array 108. System 100 may also include a first set of electronic circuits ("row drivers") 110 and a second set of electronic circuits ("column drivers") 130 for driving the LC array cells, e.g., by active-matrix addressing, as is known in the art. In existing LCD devices, each full-color pixel of the displayed image is reproduced by three sub-pixels, each sub-pixel corresponding to a different primary color, e.g., each pixel is reproduced by driving a respective set of R, G and B sub-pixels. For each sub-pixel there is a corresponding cell in LC array 108. The transmittance of each of the sub-pixels is controlled by the voltage applied to the corresponding LC cell, based on RGB data input 119 for the corresponding pixel. A timing controller (TCON) 118 receives the input RGB data and adjusts the magnitude of a signal 123 delivered to the different column drivers 130 based on the input data for each pixel. TCON 118 may also provide drivers 110 with a timing signal 121 to controllably activate rows of LC array 108, as is known in the art. The intensity of white light, e.g., provided by a back-illumination source, may be spatially modulated by LC array 108, selectively attenuating the light for each sub pixel according to the desired intensity of the sub-pixel. The selectively attenuated light passes through RGB color filter array 106, wherein each LC cell is in registry with a corresponding color sub-pixel, producing the desired color sub-pixel combinations. The

human vision system spatially integrates the light filtered through the different color sub-pixels to perceive a color image.

Brief Description Of The Drawings

The invention will be understood and appreciated more fully from the following detailed description of embodiments of the invention, taken in conjunction with the accompanying drawings of which:

Fig. 1 is a schematic block diagram of a conventional LCD color display system;

Fig. 2 is a schematic block diagram of an n-primary LCD color display system in accordance with exemplary embodiments of the invention;

Fig. 3 is a schematic block diagram of a panel control module in accordance with exemplary embodiments of the invention;

Fig. 4 is a schematic block diagram of a pixel-data converter in accordance with exemplary embodiments of the invention;

Fig. 5 is a schematic illustration of a chromaticity diagram representing the color gamut of a six-primary display in accordance with an exemplary embodiment of the invention;

Fig. 6 is schematic block-diagram of a sub-pixel processing unit in accordance with exemplary embodiments of the invention;

Fig. 7 is a schematic block-diagram of a homogeneity correction module in accordance with exemplary embodiments of the invention; and

Fig. 8 is a schematic illustration of a super-pixel arrangement in accordance with an exemplary embodiment of the invention.

It will be appreciated that for simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn accurately or to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity or several physical components included in one element. Further, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements. It will be appreciated that these figures present examples of embodiments of the present invention and are not intended to limit the scope of the invention.

Detailed Description Of Embodiments Of The Invention

In the following description, various aspects of the present invention will be described. For purposes of explanation, specific configurations and details are set forth in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be practiced without the specific details presented herein. Furthermore, some features of the invention relying on principles and implementations known in the art may be omitted or simplified to avoid obscuring the present invention.

Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "processing," "computing," "calculating," "determining," or the like, refer to the action and/or processes of an electronic circuit or computing system, or similar electronic computing device, that manipulate and/or transform data represented as physical, such as electronic, quantities within the computing system's registers and/or memories into other data similarly represented as physical quantities within the computing system's memories, registers or other such information storage, transmission or display devices. In addition, the term "plurality" may be used throughout the specification to describe two or more components, devices, elements, parameters and the like.

Embodiments of the present invention may be implemented by software, by hardware, or by any combination of software and/or hardware as may be suitable for specific applications or in accordance with specific design requirements. Embodiments of the present invention may include units and sub-units, which may be separate of each other or combined together, in whole or in part, and may be implemented using specific, multi-purpose or general processors, or devices as are known in the art. Some embodiments of the present invention may include buffers, registers, storage units and/or memory units, for temporary or long-term storage of data and/or in order to facilitate the operation of a specific embodiment.

Embodiments of the invention provide a system and method of controlling an n-primary Liquid Crystal Display (LCD), wherein n is greater than three, e.g., based on a three-primary video input signal, as described below.

Certain aspects of monitors and display devices with more than three primaries, in accordance with exemplary embodiments of the invention, are described in International Application PCT/IL02/00452, filed June 11, 2002, entitled "DEVICE, SYSTEM AND METHOD FOR COLOR DISPLAY" and published 19 December 2002 as PCT Publication WO 02/101644 ("Reference 1"), and in International Application PCT/IL02/00307, filed April 13, 2003, entitled "COLOR DISPLAY DEVICES AND METHODS WITH ENHANCED ATTRIBUTES" and published 23 October 2003 as PCT Publication WO03/088203 ("Reference 2"), the disclosure of which are incorporated herein by reference.

Reference is made to Fig. 2, which schematically illustrates an n-primary color display system 200 in accordance with exemplary embodiments of the invention.

According to exemplary embodiments of the invention, system 200 may include an n-primary LCD panel 202 to display a color image based on a three-primary video input signal 212, as described below.

According to exemplary embodiments of the invention, panel 202 may include an array 208 of liquid crystal (LC) elements (cells) 204, for example, an LC array using Thin Film Transistor (TFT) active-matrix technology, as is known in the art. For example, each of cells 204 may be connected to a horizontal ("row") line (not shown) and a vertical ("column") line (not shown), as are known in the art.

Panel 202 may also include a first set of electronic circuits 210 ("row drivers") associated with the row lines, and a second set of electronic circuits 206 ("column drivers") associated with the column lines. Drivers 210 and 206 may be implemented for driving the cells of array 208, e.g., by active-matrix addressing, as is known in the art. Panel 202 may also include an n-primary-color filter array 216 juxtaposed to array 208. In LCD devices according to some exemplary embodiments of the invention, each full-color pixel of the displayed image may be reproduced by more than three sub-pixels, each sub-pixel corresponding to a different primary color, e.g., each pixel may be reproduced by driving a corresponding set of four or more sub-pixels. For each of the four or more sub-pixel there may be a corresponding cell in LC array 208, and each LC cell may be associated with a color filter element in color filter array 216 corresponding to one of four or more, respective, primary colors. A back-illumination source (not

shown) may provide light needed to produce the color images. The transmittance of each of the sub-pixels may be controlled by controlling a voltage applied, e.g., using column drivers 206, across a corresponding LC cell of array 208, as described below.

According to exemplary embodiments of the invention, panel 202 may include s column drivers 206, each adapted to control $q=n*r/s$ columns of array 208, wherein r is the number of pixels per row of the display. For example, if $r=1280$ pixels and $n=6$ primary colors, panel 202 may include 10 column drivers 206, each to control $q=6*1280/10=768$ columns of array 208.

According to exemplary embodiments of the invention, panel 202 may also include an n-primaries panel-control module 218 to provide drivers 206 with control and/or data signals 220, and/or drivers 206 with control signals 222, for example, based on signal 212, as described in detail below. The intensity of white light provided by the back-illumination source may be spatially modulated by elements 204 of LC array 208, thereby selectively controlling the illumination of each sub-pixel according to image data for the sub-pixel. The selectively attenuated light of each sub-pixel passes through the corresponding color filter of color filter array 216, thereby producing desired color sub-pixel combinations. The human vision system spatially integrates the light filtered through the different color sub-pixels to perceive a color image.

According to exemplary embodiments of the invention, system 200 may also include a front-end module 232. Module 232 may include, for example, an analog-to-digital ("A/D") converter to convert an analog video input signal 230 into digital video input signal 212, as is known in the art. According to other exemplary embodiments signal 230 may include a digital video input signal and module 232 may not include the A/D converter.

Module 232 may optionally include a user interface (not shown), e.g., a keyboard, a mouse, and/or any type of user-interface as is known in the art. Module 232 may include any other software and/or hardware, e.g., as are known in the art.

Aspects of the invention are described herein in the context of an exemplary display system, wherein a panel control module, e.g., panel control module 218, is included within an LCD panel unit, e.g., panel 200. Although this embodiment is suitable for many commercial applications of the invention, it will be appreciated by those skilled

in the art that, according to other embodiments of the invention, the panel control module and the LCD panel may be implemented as two separate units. For example, in some embodiments, the panel control module may be implemented as part of a front-end module, e.g., module 232.

Aspects of the invention are described herein in the context of an exemplary embodiment of a panel control module, e.g., panel control module 218, and drivers, e.g., drivers 206 and 210, being separate units of a panel, e.g., panel 202. However, it will be appreciated by those skilled in the art that, according to other embodiments of the invention, the panel control module may include at least some of the drivers, e.g., as described below.

Reference is made to Fig. 3, which schematically illustrates a panel control module 300 according to exemplary embodiments of the invention.

According to exemplary embodiments of the invention, module 300 may include an input interface module 302 to receive, e.g., from front end module 232 (Fig. 2), a digital video input 320 and provide an output including a set of, e.g., parallel, three-primary pixel data signals 322 and one or more video control signals 324. For example, input 320 may include a three-primary, e.g., RGB or YCC, video signal, having a predetermined video interface, e.g., a Digital Video Interface (DVI) or a Low Voltage Differential Signaling (LVDS) interface, as are known in the art. Three-primary pixel data signals 322 may include, for example, three parallel, e.g., 8-bit or 10-bit, primary color signals, as is known in the art. Signals 324 may include any timing and/or control signals, e.g., including a Data Enable (DE) signal, a horizontal synchronize (Hsync) signal, a vertical synchronize (Vsync) signal and/or a clock signal, as are known in the art. For example, input interface module 302 may include an input interface module similar to the PanelLink® receiver available from Silicon Image of California, USA.

According to exemplary embodiments of the invention, module 300 may also include a pixel data converter 304 to convert three-primary pixel data signals 322 into a corresponding set of n-primary pixel data signals 334. For example, signals 334 may include n primary color signals, each representing a sub-pixel attenuation level on a desired bit-depth, e.g., 8-bit or 10-bit, as described below.

Module 300 may further include a sub-pixel processing unit 306 to process at least some of signals 334 and provide a sub-pixel data signal 326, e.g., an 8-bit or 10-bit signal, corresponding, for example, to a predetermined sub-pixel arrangement of a LCD panel, e.g., panel 202 (Fig. 2), as described below.

According to exemplary embodiments of the invention, module 300 may also include an output interface 308. Output interface 308 may include any suitable circuitry for converting signal 326 into one or more column driver signals 328 and/or one more row driver signals 329 of an interface technology, e.g., a Reduced Swing Differential Signaling (RSDS) interface, as is known in the art, adapted to activate one or more column drivers 310 and/or one or more row drivers 311, respectively.

According to exemplary embodiments of the invention, module 300 may further include a controller 312 to control converter 303, sub-pixel processing unit 306 and/or output interface 308, e.g., based on data of one or more of signals 324, as described below. Controller 312 may control output interface 308 using, for example, a timing control signal 337, e.g., as is known in the art.

According to exemplary embodiments of the invention, module 300 may further include a memory 314, to store, for example, attribute values corresponding to LC panel 202, as described below.

According to some exemplary embodiments of the invention, module 300 may be implemented as an integrated circuit, e.g., including interface 302, converter 304, processing unit 306, interface 308, controller 312 and memory 314. However, it will be appreciated that according to other embodiments, one or more of interface 302, converter 304, processing unit 306, interface 308, controller 312 and memory 314 may be implemented as separate elements.

Reference is made to Fig. 4, which schematically illustrates a pixel-data converter 400, according to exemplary embodiments of the invention.

According to exemplary embodiments, converter 400 may include an n-primary color conversion module 402 for converting three-primary pixel data signals 322, into n-primary pixel data signals 418. Certain aspects of methods and devices for converting image data in three-primary video formats into a at-least-three-primary format, in accordance with exemplary embodiments of the invention, are described in International

Application PCT/IL02/00410, filed May 23, 2002, entitled "DEVICE, SYSTEM AND METHOD OF DATA CONVERSION FOR WIDE GAMUT DISPLAYS" and published 12 December 2002 as PCT Publication WO 02/099557 ("Reference 3"), the disclosure of which is incorporated herein by reference.

According to some exemplary embodiments of the invention, converter 400 may also be able to manipulate at least some of signals 322 and/or signals 418, e.g., in accordance with a bit-depth enhancement method and/or a defect pixel correction method, as described below.

According to embodiments of the invention, an n-primary display system, e.g., system 200 (Fig. 2), may be able to substantially reproduce a pixel of a desired color, or a color spectrally similar to the desired color, using only at least some of the n primaries, as described below.

Reference is made to Fig. 5, which schematically illustrates a chromaticity diagram representing the color gamut of a 6-primary, e.g., red (R), green (G), blue (B), cyan (C), yellow (Y) and magenta (M), display in accordance with an exemplary embodiment of the invention.

For the six primary colors illustrated in Fig. 5, a selection of a triad of primary colors may define an effective color gamut, e.g., effective color gamut 1502 may be defined by a YMR triad. According to embodiments of the invention, in order to reproduce a pixel within a desired color gamut, a triad of primary colors may be selected such that an effective color gamut defined by the selected triad may substantially reproduce the desired color gamut, as explained in detail in Reference 2. An effective color gamut may be defined by different color triads, e.g., effective color gamut 1504 may be defined by triads RGB and YCM. Selection of the three primary colors from a set of available triads defining a required effective color gamut may include optimization of display attributes, for example, luminance uniformity, smoothness, or any other objective, subjective or relative display attribute.

According to exemplary embodiments of the invention, a pixel of a desired color within a given color gamut may be reproduced using only $l<n$ of the n sub-pixels, assuming that the effective color gamut defined by the l sub-pixels includes, i.e., is capable of reproducing, the desired color. For example, a pixel having a color included in

field 1502 may be reproduced using only the Y, R and M sub-pixels, e.g., without using the G, C and B sub-pixels.

According to some exemplary embodiments of the invention, if the effective color gamut defined by the l sub-pixels does not include, i.e., is not capable of reproducing, the desired color, then a color which is similar to the desired color, or as similar as possible to the desired color, may be reproduced using the l sub-pixels. Additionally or alternatively, a desired color of a pixel may be reproduced by adjusting values of one or more sub-pixels of neighboring pixels. As a result of this adjustment, the adjusted neighboring pixels and/or sub-pixels may be spatially integrated by a viewer to substantially reproduce the desired color.

A selection of a larger number of primary colors, e.g., four or five primary colors, may result in a wider effective color gamut. For example, an effective color gamut including fields 1502, 1504 and field 1506 may be obtained by selecting four primary colors, e.g., C, M, R and Y. Accordingly, the larger the number n of primary colors used by the display, the larger the color gamut that may be reproduced using only some of the sub-pixels.

The ability to reproduce a pixel of a desired color using only some of the n sub-pixels may be advantageous for pixel bit-depth enhancement, e.g., as described in Reference 2, and/or for defective pixel correction, as described below.

A defective pixel may include one or more defective sub-pixels. The defective sub-pixels may include either sub-pixels constantly being in an "open", i.e., un-attenuated, state and/or sub-pixels constantly being in a "closed", i.e., fully attenuated, state.

According to exemplary embodiments of the invention, information regarding defective pixels of a display, e.g., including a location of each defective pixel and/or the identity of one or more defective primary color sub-pixels in the defective pixel, may be recorded, for example, during a testing procedure applied to the display. The testing procedure may include any testing procedure suitable for detecting defective sub-pixels of the display. For example, the testing procedure may include a testing procedure as described in *Noam Cohen, "Automated Optical Inspection for the LTPS TFT-LCD Process", http://www.orbotech.com/tech_lib_fpd.asp?sub=aoi_ltps_tft.* The information

obtained by such a testing procedure may be subsequently used in order to enable a defective pixel to reproduce a desired color based on input pixel data, e.g., three-primary or more-than three-primary data, as described below.

According to exemplary embodiments of the invention, a set of i defective pixel types may be defined, based on the defective pixel information. For example, in a six-primary GCBMRY display, a first defective pixel type may correspond to a pixel including a defective R sub-pixel, a second defective pixel type may correspond to a pixel including a defective G sub-pixel, a third defective pixel type may correspond to a pixel including a defective C sub-pixel, a fourth defective pixel type may correspond to a pixel including a defective B sub-pixel, a fifth defective pixel type may correspond to a pixel including a defective Y sub-pixel, and a sixth defective pixel type may correspond to a pixel including a defective M sub-pixel. Other defective pixel types may also be defined, e.g., defective pixel types corresponding to a pixel including more than one defective sub-pixels.

According to exemplary embodiments of the invention, a set of j color conversions may be determined for converting input pixel data into l_j-primary pixel data, wherein l_j denotes a predetermined number of primaries. The color conversions may correspond to the defective pixel types, and/or to bit-depth enhancement of a pixel, e.g., as described in Reference 2. For example, a color conversion for converting RGB pixel data into RGCBY pixel data may correspond to the sixth defective pixel type and/or to a bit depth enhancement of a pixel having a color gamut reproducible by the RGCBY primaries. A color conversion for converting RGB pixel data into RGCB pixel data may correspond to a pixel including defective M and Y sub-pixels and/or to a bit depth enhancement of a pixel having a color gamut reproducible by the RGCB primaries.

Aspects of methods and systems for conversion of image data in three-primary formats into an at-least-three-primary format, in accordance with exemplary embodiments of the invention, are described in Reference 3. According to other embodiments of the invention, any other suitable conversion algorithm, e.g., a conversion algorithm using a 3 x l_j color conversion matrix, may be implemented for converting image data in three-primary formats into a l_j-primary format.

Thus, according to exemplary embodiments of the invention, pixel data, e.g., three-primary pixel data, intended to be reproduced by a defective pixel may be converted, e.g., as described in Reference 3, into converted pixel data using a color conversion method suitable for the type of defect of the defective pixel. Pixel data, e.g., three-primary pixel data, intended to be reproduced by a "benign", i.e., non-defective pixel, may be converted into converted pixel data using a bit-depth enhancement color conversion method, e.g., as described in Reference 2.

Referring back to Fig. 4, according to some exemplary embodiments, converter 400 may also include an l_j-primary conversion module 416 able to convert three-primary pixel data, e.g., of signals 322, into corresponding l_j-primary pixel data signals 422. For example, module 416 may include a conversion module analogous to the converter described in Reference 3 for converting the pixel data of signals 322 into at-least-three-primary data.

According to exemplary embodiments of the invention, controller 312 may be able to determine, e.g., based on one or more of signals 324, a pixel of the display intended to reproduce the pixel data of signals 322. For example, controller 312 may include a counter to count the number of Hsync and/or clock signals. Based on the number of Hsync and/or clock signals, controller may be able to determine the pixel intended to reproduce the pixel data of signals 322. Controller 312 may also be able to determine whether the pixel intended to reproduce the pixel data of signals 322 is a defective pixel or a "benign" pixel. For example, controller 312 may compare the determined position of the pixel with pre-obtained defective pixel information, which may be stored in memory 314. The defective pixel information may also include, for example, the type of the defective pixel. The defective pixel information may further include parameters, e.g., a color conversion matrix, of an l_j-primary conversion related to the defective pixel. Alternatively, controller 312 may be able to select the parameters of the l_j-primary conversion, e.g., based on the defective pixel type.

According to exemplary embodiments of the invention, if the pixel intended to reproduce the pixel data of signals 322 is a defective pixel, then controller 312 may select an l_j-primary color conversion related to the type of the defective pixel, as described above. If the pixel intended to reproduce the pixel data of signals 322 is a benign pixel,

then controller 312 may select an l_j-primary color conversion corresponding to a bit-depth enhancement of the pixel, as described in Reference 2. Controller 312 may provide the parameters of the selected l_j-primary conversion to module 416.

According to exemplary embodiments of the invention, n-primary conversion module 402 may also provide an initial combination parameter signal 408 corresponding to the pixel data of signals 322, which may be used as part of the pixel bit-depth enhancement, e.g., as described in Reference 2. Converter 400 may also include a multiplexer 406 to receive signal 408 and produce a selected combination-parameter signal 420, for example, having either a zero value or the value of signal 408, e.g., according to a control signal 412, which may be provided by controller 312. Converter 400 may also include a combiner 404 able to combine signals 418 and signals 422 into a set of n-primary pixel data signals 434, e.g., based on the value of signal 420, as described below. For example, signals 434 may include *n*, e.g., parallel, primary color signals.

According to exemplary embodiments of the invention, controller 312 may control multiplexer 406, e.g., using signal 412, to provide signal 420 having a zero value, e.g., if the pixel data of signals 322 is intended to be reproduced by a defective pixel. As a result, n-primary pixel data signals 434 may include only pixel data of signals 422. Controller 312 may control multiplexer 406, e.g., using signal 412, to provide signal 420 having the value of signal 408, e.g., if the pixel data of signals 322 is intended to be reproduced by a benign pixel. As a result, n-primary pixel data signals 434 may include a combination of n-primary pixel data of signals 418 and l_j-primary pixel data of signals 422.

Thus, signals 434 may include enhanced bit-depth pixel data, e.g., if the pixel data of signals 322 is intended to be reproduced by a benign pixel, or defect-corrected pixel data, e.g., if the pixel data of signals 322 is intended to be reproduced by a defective pixel.

Reference is made to Fig. 6, which schematically illustrates a sub-pixel processing unit 600 according to exemplary embodiments of the invention.

According to exemplary embodiments of the invention, processing unit 600 may include a sub-pixel spatial processing module 602 able to process n-primary pixel data

signals 334 of one or more pixels and to provide spatially processed data signals 603, e.g., according to a control and/or timing signal 610 received from controller 312. Processing module 602 may implement any suitable sub-pixel spatial processing algorithm, e.g., for spatial scaling and/or filtering n-primary pixel data of signals 334, e.g., as described in Reference 1 and/or Reference 2. Processing module 602 may include a memory 612 to store data corresponding to one or more pixels, which may be used, for example, as part of at least some of the spatial processing algorithms.

According to exemplary embodiments of the invention, sub-pixel processing unit 600 may optionally include a homogeneity correction module 604, as described in detail below.

The back-illumination source of system 200 (Fig. 2) may include a plurality of fluorescent lamps, or any other suitable white light source, the light of which may pass through one or more homogenizers, as are known in the art. Such configuration may result in an undesirable variation of viewed brightness across the display. In order to minimize this non-homogeneity, it may be desired to maintain a relatively fixed ratio between the brightness values of the different primaries across the display.

A variation of the brightness values of each of the primaries across the display may be determined, e.g., during a testing process, and based on the brightness variation, a set of position-dependent correction factors corresponding to each of the primary colors may be calculated. For example, each of the correction factors may correspond to one of the primaries and a position on the display. Data representing the position-dependent correction factors corresponding to each of the primary colors may be stored, for example, in memory 314. The correction factor data may be subsequently used in order to correct a brightness variation across the display, as described below.

According to exemplary embodiments of the invention, homogeneity correction module 604 may be able to multiply a value of each one of signals 603 by a respective correction factor to produce homogeneity-corrected pixel data signals 605, as described below.

Reference is made to Fig. 7, which schematically illustrates a homogeneity correction module 700 according to exemplary embodiments of the invention.

According to exemplary embodiments of the invention, controller 312 may determine, e.g., based on one or more of signals 324, a position of a pixel of the display intended to reproduce the pixel data of signals 603, as described above. Controller 312 may then retrieve from memory 314 a set of, e.g., *n*, correction factors corresponding to the determined pixel position, and provide module 700 with a set of, e.g., *n*, signals 704 having the value of the retrieved set of, e.g., *n*, correction factors, respectively.

Module 700 may include a set of, e.g., *n*, multipliers 702 to provide a set of, e.g., *n*, signals 705 having values corresponding to a multiplication of the values of the set of signals 603 by correction factor values of set of signals 704, respectively.

According to some exemplary embodiments of the invention, the correction factor values may be stored in memory 314 at a reduced resolution, e.g., including only some of the correction factor values. Correction factor values not stored in memory 314 may be calculated, e.g., by controller 312, using a suitable interpolation method.

Referring back to Fig. 6, according to exemplary embodiments of the invention, sub-pixel processing unit 600 may also include an addresser 606 to process pixel data 605 and provide sub-pixel data signal 326 including sub-pixel data in an order corresponding to a predetermined sub-pixel arrangement of panel 202 (Fig. 2), as described in detail below.

According to exemplary embodiments of the invention, panel 202 (Fig. 2) may include a predetermined sub-pixel arrangement, e.g., as described in Reference 1 or Reference 2. For example, panel 202 (Fig. 2) may include a super-pixel arrangement including a predetermined, fixed, number of n-primary pixels, each n-primary pixel including one color sub-pixel element of each of the n primary colors, as described in Reference 1.

According to exemplary embodiments of the invention, addresser 606 may receive n-primary signals 605 and arrange them in an order corresponding to a physical sub-pixel order, e.g., within the rows of LC array 208 (Fig. 2), such that drivers 210 and/or 206 (Fig. 2) may activate respective sub-pixels of LC array 208 (Fig. 2) in accordance with the data of signal 212 (Fig. 2).

Reference is also made to Fig. 8, which schematically illustrates a super-pixel arrangement 800 according to an exemplary embodiment of the invention.

According to the exemplary embodiment of Fig. 8, if the drivers activate the sub-pixels of each row of array 204 (Fig. 2) sequentially, then addresser 606 may receive n-primary data signals 605 corresponding to all the pixels within super-pixel 800 and may address the sub-pixel values to the corresponding physical sub-pixel, e.g., according to the following order: "RGYB" in the first row, "CRGY" in the second row, "BCRG" in the third row, etc. Addresser 606 may include any suitable hardware and/or software, e.g., as described in Reference 1. Addresser 606 may also include a memory 618 for storing pixel data of one or more of the n-primary pixels corresponding to the super pixel, e.g., data of sub-pixels to be displayed in subsequent rows.

In other exemplary embodiments, the arrangement of sub-pixels may include a spatially periodic pattern including a smaller number of sub-pixels corresponding to one or more predetermined primary colors, e.g., blue and cyan, compared to the number of sub-pixels corresponding to other primary colors, e.g., as described in US provisional Application 60/535,541 filed January 12, 2004 and entitled "METHOD AND SYSTEM OF UPDATING A MEMORY OF A COLOR DISPLAY", the disclosure of which is incorporated herein by reference. In such embodiments, addresser 606 may be able to process the n-primary data signals 605 corresponding to two or more neighboring pixels and provide signal 326 including a smaller number of, e.g., blue and cyan, sub-pixel values compared to the number of sub-pixel values corresponding to other primary colors. For example, addresser 606 may be able to calculate a weighted average of two or more sub-pixel values of two or more neighboring pixels intended to be displayed by one sub-pixel, e.g., a blue or cyan sub-pixel, of the display.

According to some exemplary embodiments of the invention, addresser 606 may also implement, for example, one or more sub-pixel correction methods for correcting a vertical and/or horizontal shift of an effective (color-weighted) center of the n-primary pixel, as described in Reference 1. This may be achieved, for example, by performing an interpolation between values of one or more sub-pixels of a pixel and/or of neighboring pixels. The interpolation may be linear, cubic or of any other suitable form, as described in References 1 and/or 2. Addresser 606 may also be able to perform a "smoothing" (low-pass filtering) operation, for example, in order to reduce a color fringes effect of a displayed graphic object, e.g., a character of a certain font. According to this exemplary

embodiment, the value of at least some of the sub-pixels may be affected by more than one pixel, and a weighted average function may be applied by addresser 606 in order, for example, to reduce the color fringes effect. Memory 618 may be used to store sub-pixel values of one or more pixels neighboring the pixel to be displayed. Memory 618 may also be used to store pixel data corresponding to one or more rows of the display, e.g., if processing pixel data of one or more rows is required, e.g., as described in References 1 and/or 2.

Although according to some of the embodiments, the processing methods described above may be performed by addresser 606 on signals 605, according to other embodiments some of the processing methods may be performed on signals 603 and/or 334. For example, processor 602 may be adapted to process signals 334 according to at least some of the processing methods described above with reference to addresser 606.

According to some exemplary embodiments of the invention, drivers 310 (Fig. 3) and/or drivers 311 (Fig. 3) may be integrated as part of panel control module 218 (Fig. 2), and the format of the control and/or timing signals provided to drivers 310 and/or 311 may be preset. According to these embodiments, addresser 606 may be adapted to directly provide drivers 311 and/or drivers 310 with control and/or timing signals in the preset format, e.g., signals 329 and/or 328, obviating the need for output interface 308 (Fig. 3).

While certain features of the invention have been illustrated and described herein, many modifications, substitutions, changes, and equivalents will now occur to those of ordinary skill in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

CLAIMS

1. A system substantially as shown and described hereinabove.
2. A system substantially as illustrated in any of the drawings.
3. A method substantially as shown and described hereinabove.
4. A method substantially as illustrated in any of the drawings.

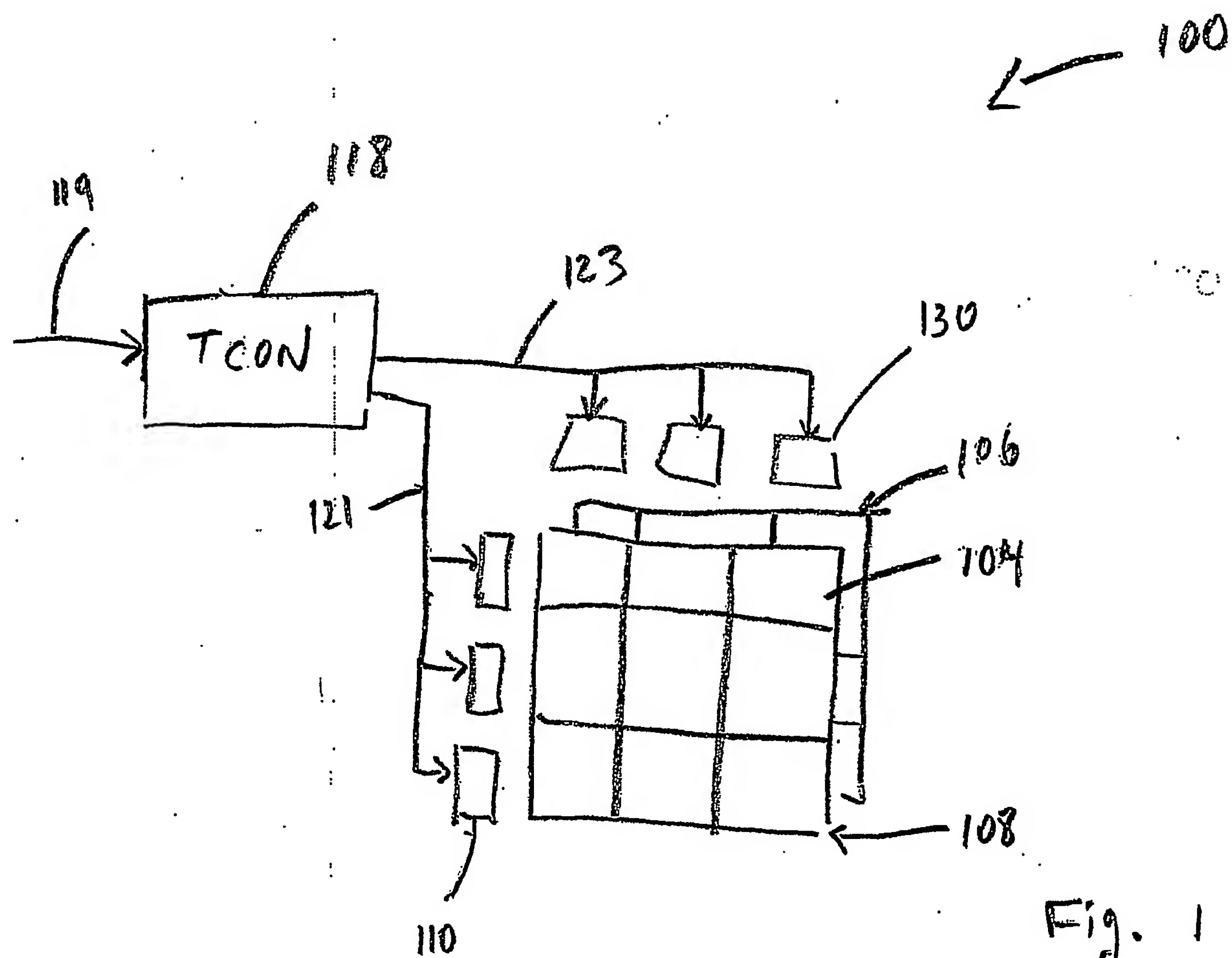
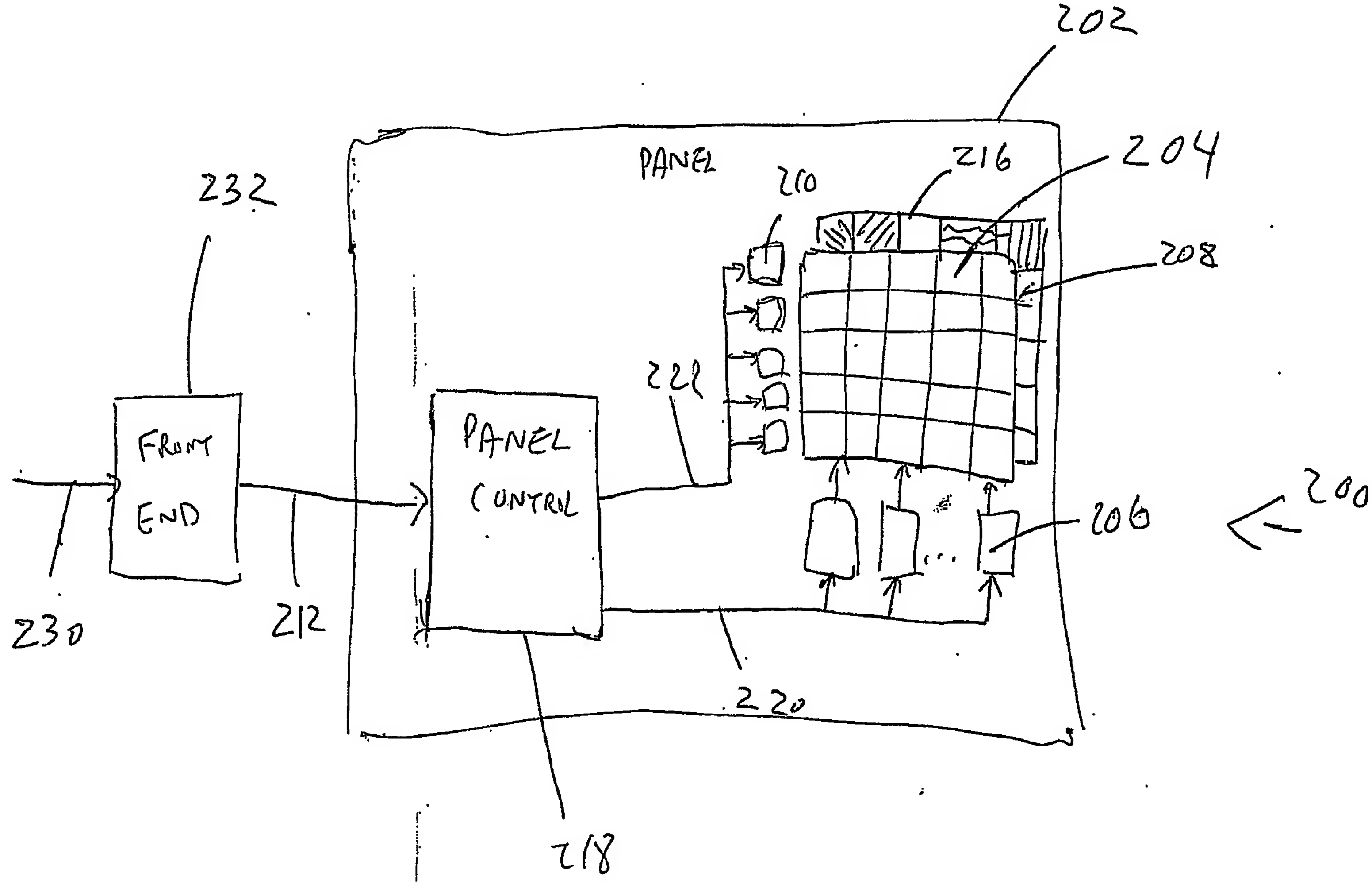
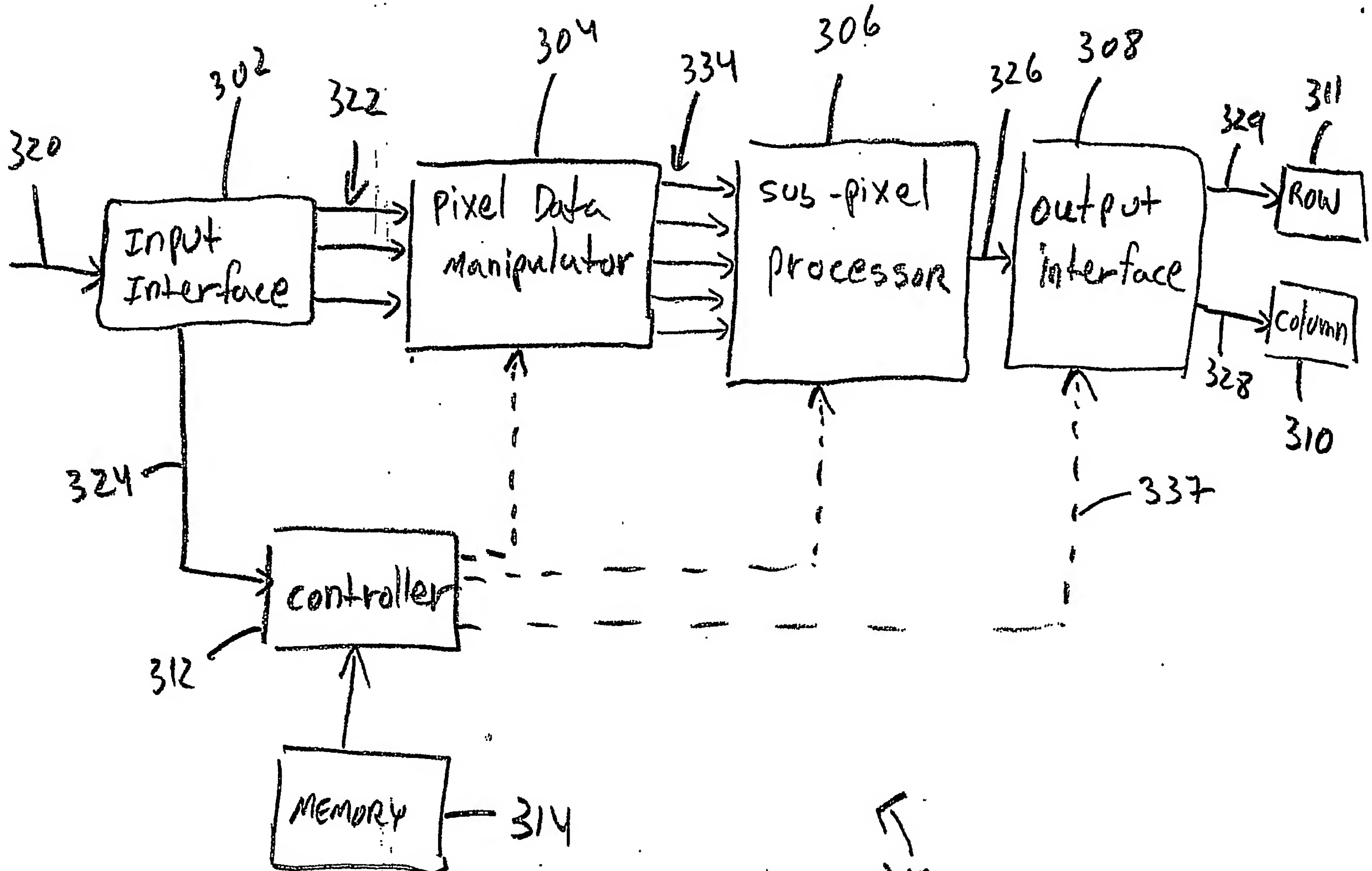


Fig. 1



202
204
208
216
210
PANEL
222
PANEL CONTROL
206
200
220
218
232
FRONT END
230
212

Fig. 2



Input Interface
Pixel Data manipulator
sub-pixel processor
output interface
ROW
column
controller
MEMORY
320
302
322
304
334
306
326
308
329
311
328
310
324
312
314
337
300

Fig. 3

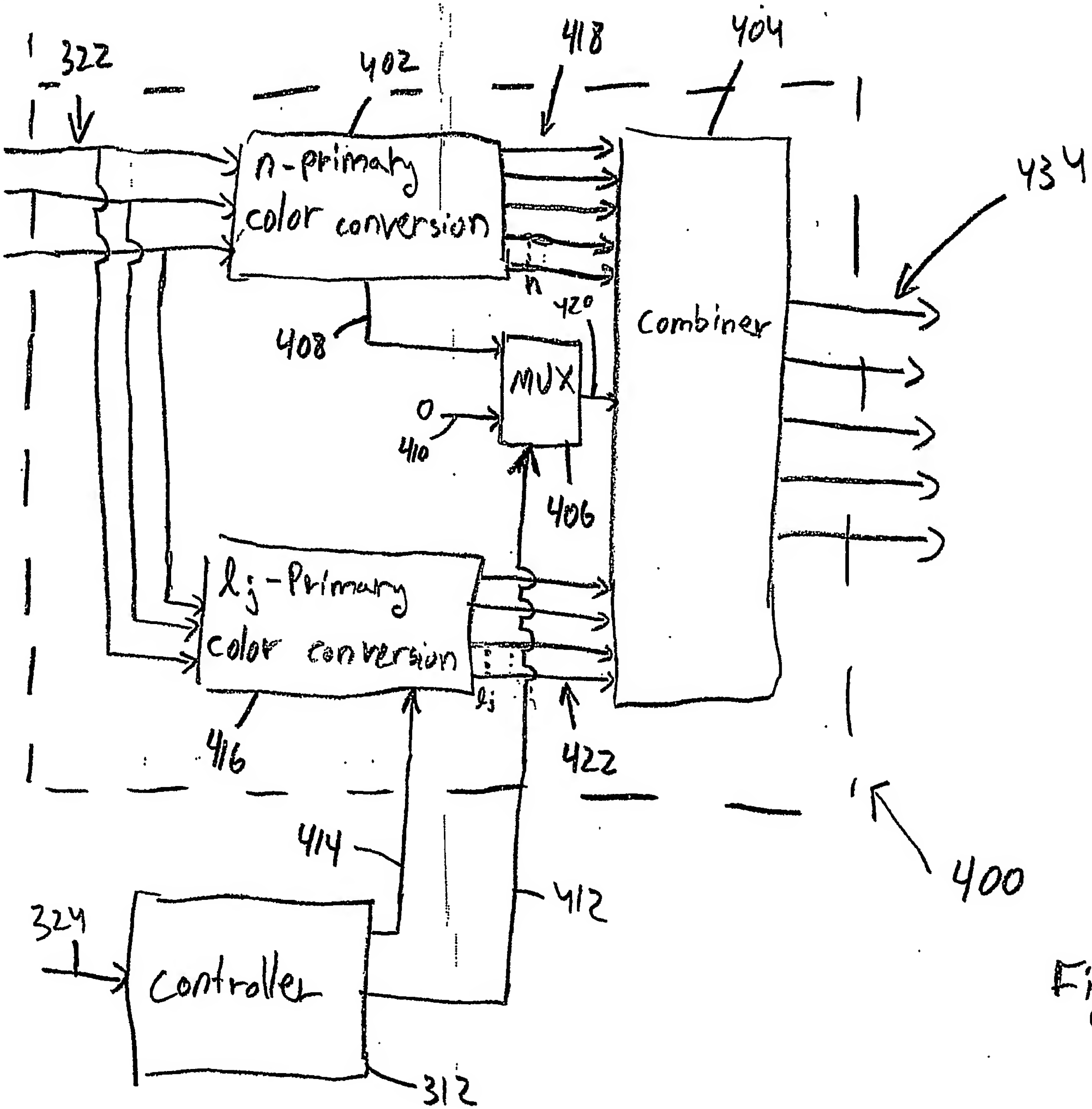

322
402
418
404
n-primary color conversion
n
420
408
MUX
0
410
406
Combiner
434
l_j-Primary color conversion
l_j
416
422
414
412
324
Controller
312
400

Fig. 4

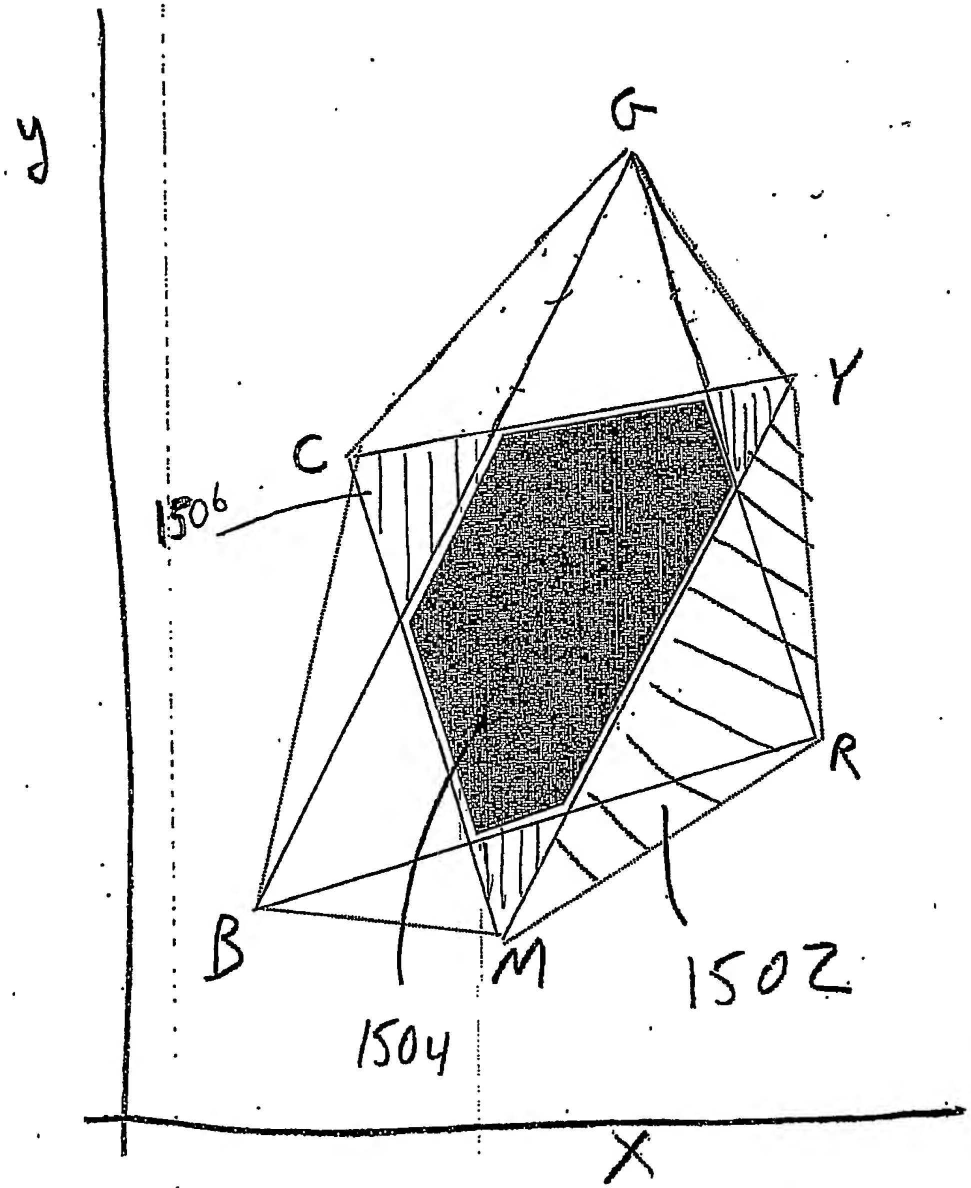


Fig. 5

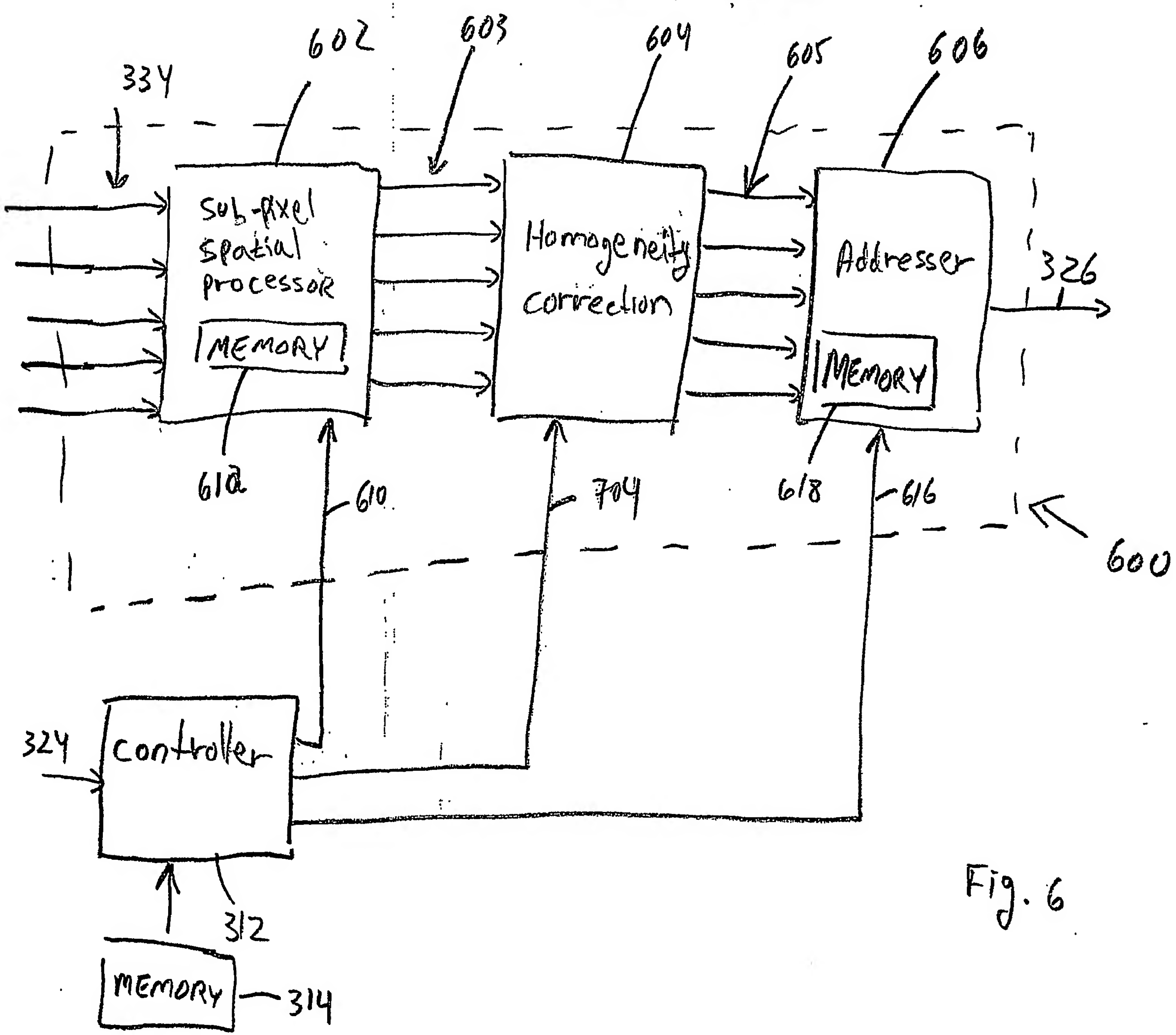

602
603
604
605
606
334
Sub-pixel spatial processor
MEMORY
Homogeneity correction
Addresser
MEMORY
326
612
610
704
618
616
600
324
controller
312
MEMORY
314

Fig. 6

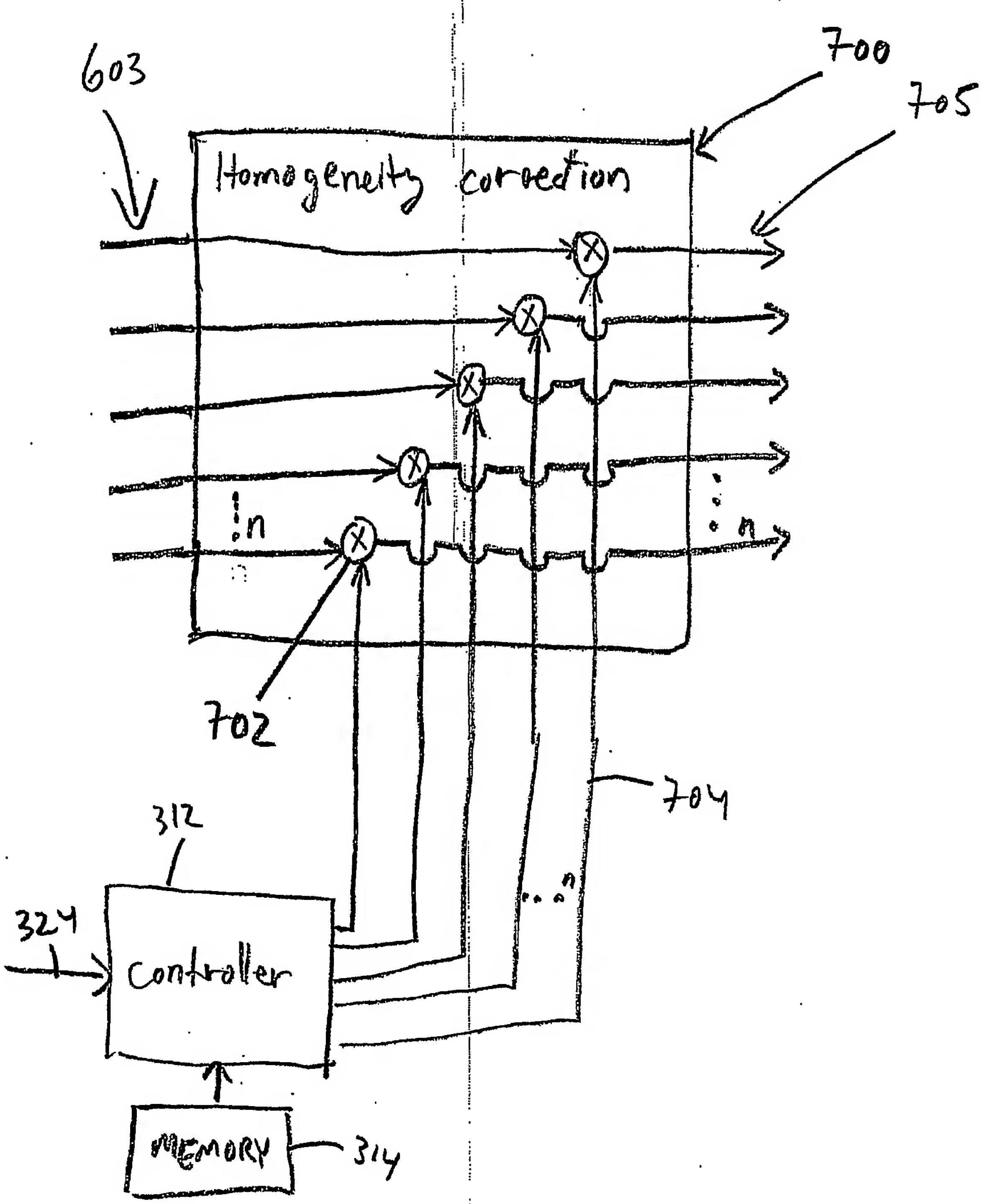

603
700
705
Homogeneity correction
n
n
702
704
n
312
324
Controller
MEMORY
314

Fig. 7

R	G	Y	B	C	R	G	Y
C	R	G	Y	B	C	R	G
B	C	R	G	Y	B	C	R
Y	B	C	R	G	Y	B	C
G	Y	B	C	R	G	Y	B
R	G	Y	B	C	R	G	Y

Fig. 8